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WIND TUNNEL WALL INTERFERENCE

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[redacted] TUNNEL WALL INTERFERENCE RESEARCH

About a decade ago, interest in alleviating wind tunnel wall interference was renewed by advances in computational aerodynamics, concepts of adaptive test section walls, and plans for high Reynolds number transonic test facilities. Selection of the NASA Langley cryogenic concept for the National Transonic Facility (NTF) tended to focus our renewed wall interference efforts. A brief overview and current status of some Langley sponsored transonic wind tunnel wall interference research are presented. Included are continuing efforts in basic wall flow studies, wall interference assessment/correction (WIAC) procedures, and adaptive (flexible) wall technology. It should be pointed out that for transonic flow conditions, wind tunnel wall interference is coupled to other tunnel flow phenomena not generally associated with subsonic flow and classical (linear) wall interference theory. Some of these related phenomena, such as flow quality, support interference, flow diagnostics, and transition studies, are discussed in other papers in this compilation. Understanding these phenomena is basic to proper unbounded-flow simulation in wind tunnels; however, it is not appropriate to repeat the material in this brief overview. Furthermore, much of what should be included here cannot be; a list of publications from Langley sponsored research over the past decade or so is included in order to summarize the total effort and to identify some of the individual researchers who have been involved.

NASA Langley focus is transonic

- Basic wall flow studies
- Assessment/correction procedures - WIAC
- Adaptive wall technology - flexible

BASIC WALL FLOW STUDIES

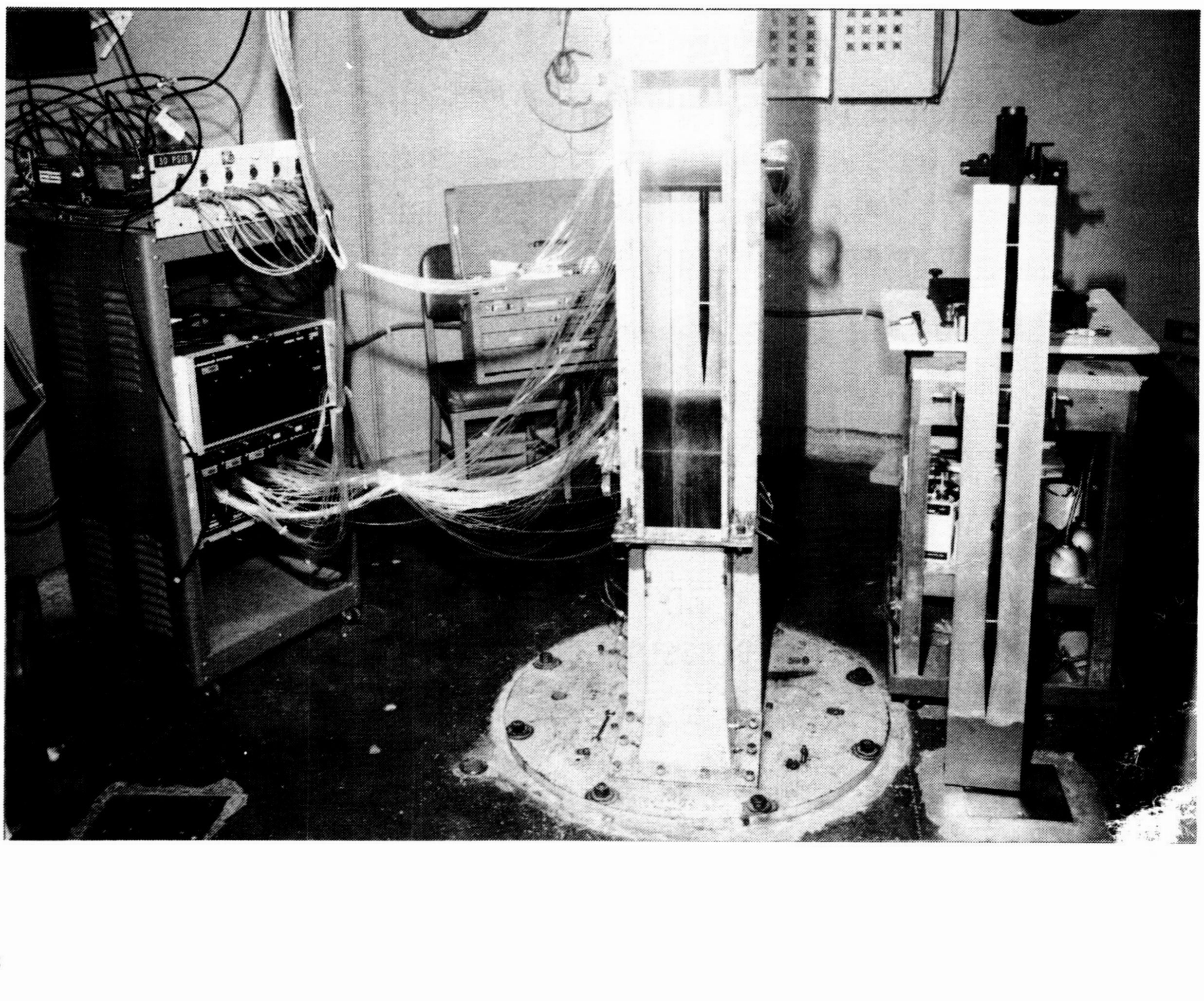
In order to emphasize specific wall interference aspects, the basic wall flow studies summarized here have been grouped as slotted wall test sections, sidewall boundary-layer phenomena, wall interference data bases, and tunnel simulator code development. Activities pertaining to slotted test section walls include parametric studies of wall properties, use of such information in NTF test section design, and subscale design verification tests. These efforts are considered as customary wall interference research. Activities dealing with the response of the (solid) sidewall boundary layer to the model pressure field and its resulting influence on the test conditions are not so customary. It is primarily observed in airfoil testing and should be accounted for or alleviated; its influence is much less in 3-D. NASA Langley work in this area includes theory, experiment, and applications. Wall interference data bases and numerical wind-tunnel flow simulator codes are required for the development and verification of assessment/correction (WIAC) procedures; in addition, these pursuits have their own intrinsic value. Both 2-D and 3-D data bases, including wall pressure signature data, are being generated. Tunnel simulator CFD codes are being continually developed; governing flow equations include linear, transonic potential, and nonpotential approximations. The paper by South et al. in session 1 of this compilation is an example of our work in this area.

- Slotted test section walls
  - 6- by 19-inch TT parametric studies
  - NTF design/subscale NTF tests
- Sidewall boundary layer phenomena
  - Theory and experiment
  - Applications
- Wall interference data bases
  - 2D and 3D
  - Wall pressure data
- Tunnel simulator code development
  - Linear and transonic potential
  - Nonpotential

SLOTTED WALL PARAMETRIC STUDIES

6- by 19-Inch TT

The experimental phase of Langley's most recent parametric slotted wall flow study was conducted by Joel Everhart throughout 1984 in the 6- by 19-inch Transonic Tunnel (TT). His experimental setup is shown in the photograph; the single-slot test section wall configuration standing at the right has been removed, exposing the airfoil and opposite wall. A flow angularity probe is visible in the slot of the far wall, just ahead of the leading edge of the model. Pressure data were taken on the walls and model; flow angularity data were also taken in the test section. Variation of wall parameters was by means of readily interchangeable test-section "upper and lower" slotted-wall configurations. Wall parameters varied in this study include geometric openness ratio, number of slots at fixed openness, slat thickness, slat lip radius-of-curvature, and sidewall boundary-layer thickness. This was done using a 6-inch-chord NACA 0012 airfoil over a range of angles of attack (-4° to $+4^{\circ}$) and tunnel Mach numbers (0.1 to 0.95). Data from this study are now being reduced; hopefully these data will aid in understanding the role of such parameters in the slotted-wall boundary condition.



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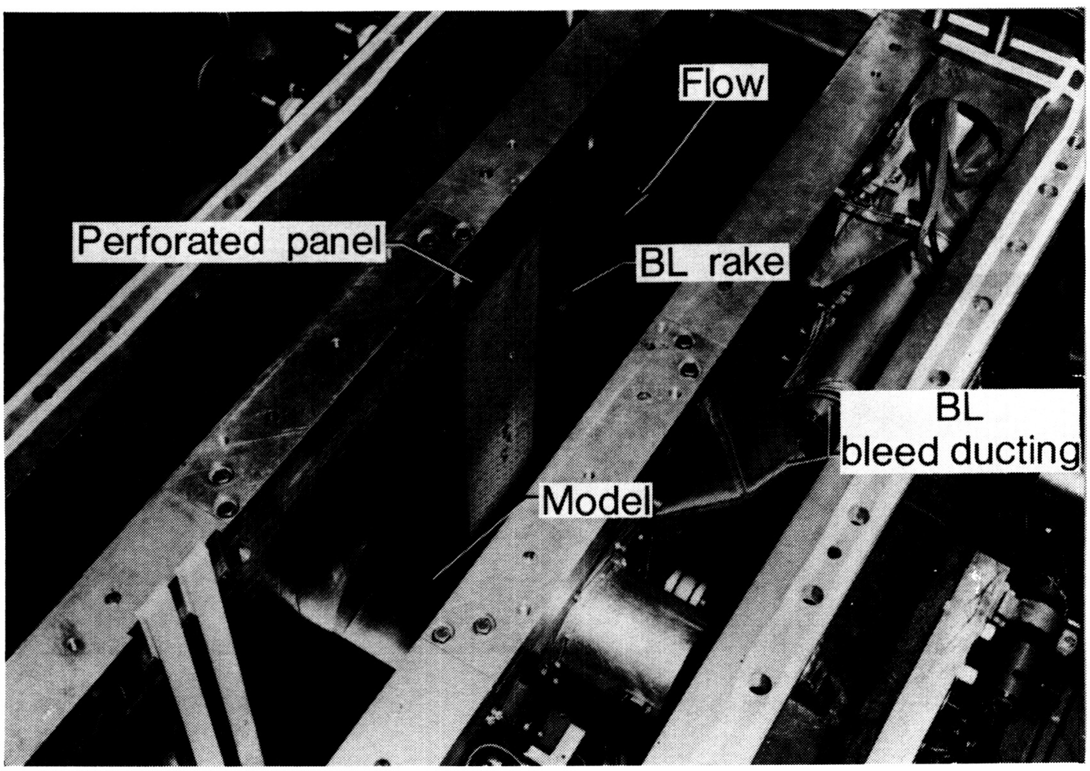
SIDEWALL BOUNDARY LAYER CONTROL

8- by 24-Inch Airfoil Test Section, 0.3-M TCT

The 0.3-m TCT sidewall boundary layer removal hardware consists of a pair of perforated panels inserted (flush-mounted) in the tunnel sidewalls upstream of the model location. These perforated panels extend from the floor to the ceiling of the test section and are approximately 6 inches wide, as shown in the top view photograph of the test section (top of the plenum chamber and the slotted wall removed). Visible in this photograph are the airfoil model, boundary layer bleed ducting, one of the four boundary layer sidewall rakes, and one of the two perforated panels. The holes in it were drilled using an electron beam technique and the surface was etched; this results in an unusually smooth surface considering the large number of holes in the plate. Two different hole configurations giving different porosities have been tested. The amount of the boundary layer mass flow removed from either of the sidewalls is controlled independently by two digital flow control valves and discharged directly to the atmosphere (passive system). At a Mach number of 0.76, the maximum bleed flow rate is about 2 percent of the test section mass flow rate; this amount of bleed capability is sufficient to significantly reduce the sidewall boundary layer displacement thickness. Recently, a cryogenic reinjection compressor (active system) has been installed and validated; the sidewall boundary layer mass removal capability has been expanded to cover the entire operating envelope of the 0.3-m TCT.

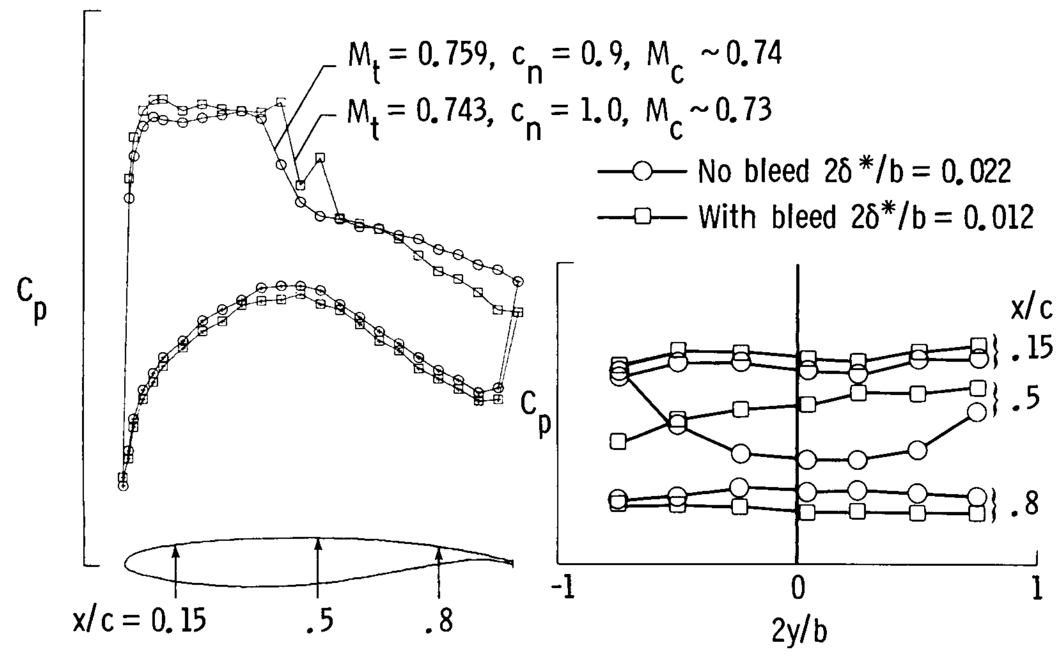


EFFECT OF SIDEWALL BOUNDARY LAYER BLEED

0.3-M TCT

The adverse influence of the sidewall boundary layer/model pressure field interaction on an airfoil test is most pronounced at supercritical flow conditions. Barnwell and Sewall have shown that for attached flow on the sidewall, the Mach number correction is approximately $-2\delta^*/b$, where b is the tunnel span. When the airfoil shock waves intersecting the sidewall separate the sidewall boundary layer, then the resulting flow is very 3-D in nature; one tries to prevent this situation. In the 0.3-m TCT airfoil tests, the effect of upstream sidewall boundary layer bleed is most easily observed at supercritical flow conditions with high lift. Shown in the figure are midspan chordwise and several spanwise presure distributions on an airfoil at the nominal tunnel conditions shown in the subtitle. Results are for tests without (○) and with (□) bleed (passive system); test section Mach numbers (M_t) and their corrected values (M_c), using Barnwell-Sewall approximations, are also given. As can be seen on the left, with bleed applied, there is an improvement of the midspan pressure recovery on the upper surface near the trailing edge of the airfoil; this suggests that with bleed the separation on the upper surface is significantly reduced. The more downstream location of the shock wave and higher normal force coefficient for the lower test section Mach number also indicate less separation. The spanwise distributions are on the right; at x/c = 0.5 it is seen that the separation induced by the shock is at the sidewalls. The flow appears to be less 3-D with bleed applied.

0.3 m TCT, $M_{\infty,t} = 0.76$, $R_c = 6 \times 10^6$, $\alpha = 4°$



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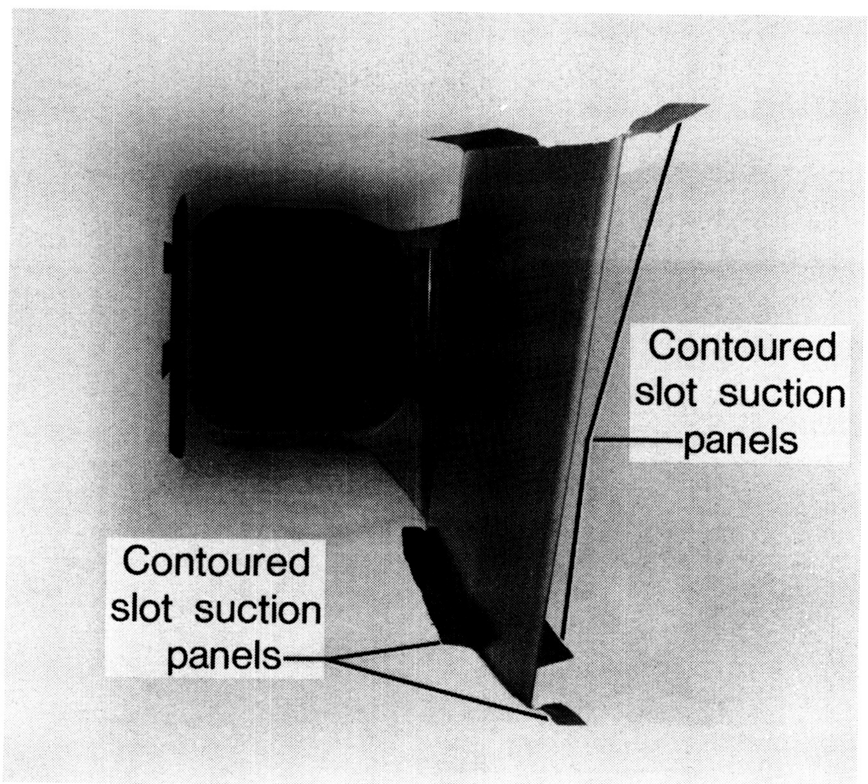
SIDEWALL BOUNDARY LAYER CONTROL

LFC Experiment, 8-Ft TPT

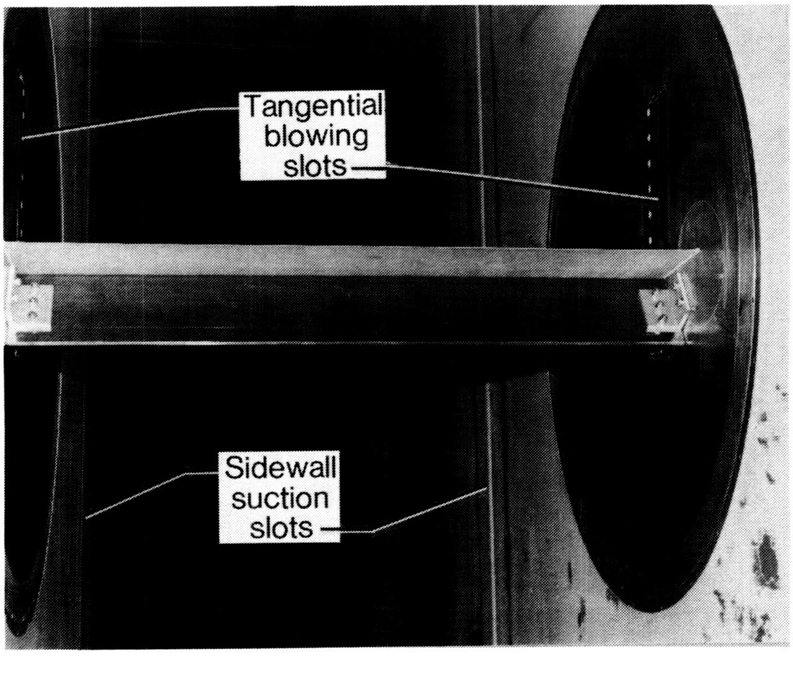
Suction requirements under the turbulent boundary layer of the contoured test-section liner near the model and on the model surfaces near the liner were determined as part of the liner-design procedure. This was done in the process of determining the effective displacement correction which had to be accounted for in the liner shape. Determination of the suction requirements in these turbulent-flow regions is not to be confused with what is required to determine the laminar-flow-region suction rates over most of the model. Suction is required on the liner "endplates" near the model juncture in order to keep the turbulent boundary layer attached through the adverse pressure-gradient regions which occur in the following regions: on approaching the model leading edge, through the aft-portion pressure-recovery regions, and near the concave corners on the lower surface. The liner blocks in these regions form a collar about the model containing suction panel blocks with slot/plenum/duct construction very similar to that used on the wing. These blocks are metal, but with molded fiberglass outer skin; they move with the model through angle-of-attack adjust-ments. The figure is a photograph looking downstream through the channel "above" the wing surface, and the suction panel blocks are the dark areas on the top and bottom liner "endplates."



SIDEWALL BOUNDARY LAYER CONTROL

LTPT

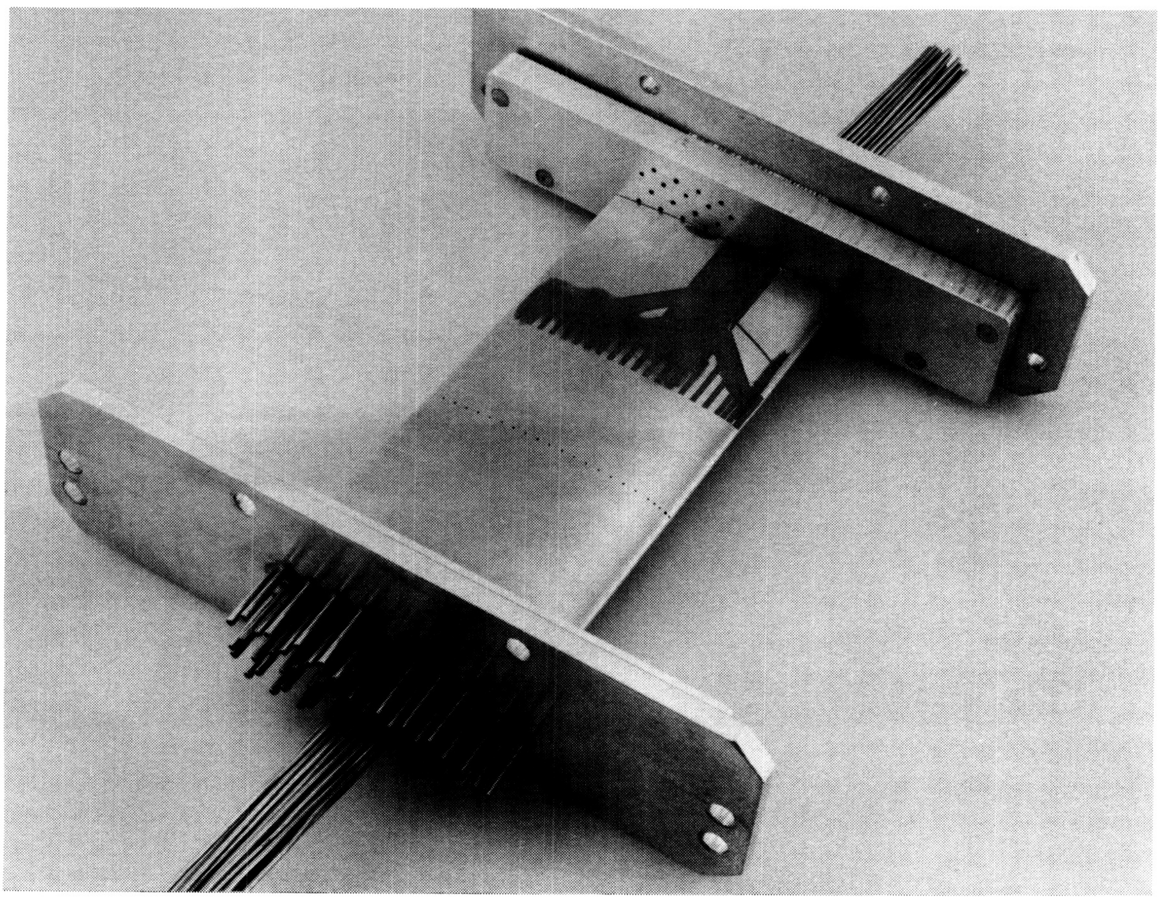
In order to reasonably approach two dimensionality in low-speed flows when testing multielement airfoils, some form of tunnel sidewall boundary layer control is needed. The large adverse pressure gradients induced by the high-lift airfoil can cause the tunnel sidewall boundary layer to separate and result in a decrease in airfoil lift. Tangential blowing was selected to provide local sidewall BLC near the airfoil; overall boundary layer thinning upstream of the model is accomplished by single suction slots on each sidewall. Five blowing boxes with tangential slots are available for each side of the tunnel and can be positioned around the airfoil within the confines of the endplates. High-pressure air is supplied to each box through a flexible hose connected to a mobile blowing-box control cart. The tangential wall blowing energizes the sidewall boundary layer, appreciably reducing its displacement thickness. The photograph is a view looking into the trailing edge of a "poor man's" split flap model. Single blowing-box tangential slots are seen on each turntable above the model in the adverse pressure recovery region above the upper airfoil surface. Ahead of the leading edge, the sidewall suction slots are visible. These span each sidewall from top to bottom. In earlier tests on an NACA 4416 airfoil with flap, it was found that tangential blowing through slots located on the model endplates eliminated flow separation at the flap and sidewall juncture. It is required to obtain useful results from two-dimensional tests of high-lift multielement airfoils.



SIDEWALL BOUNDARY LAYER CONTROL

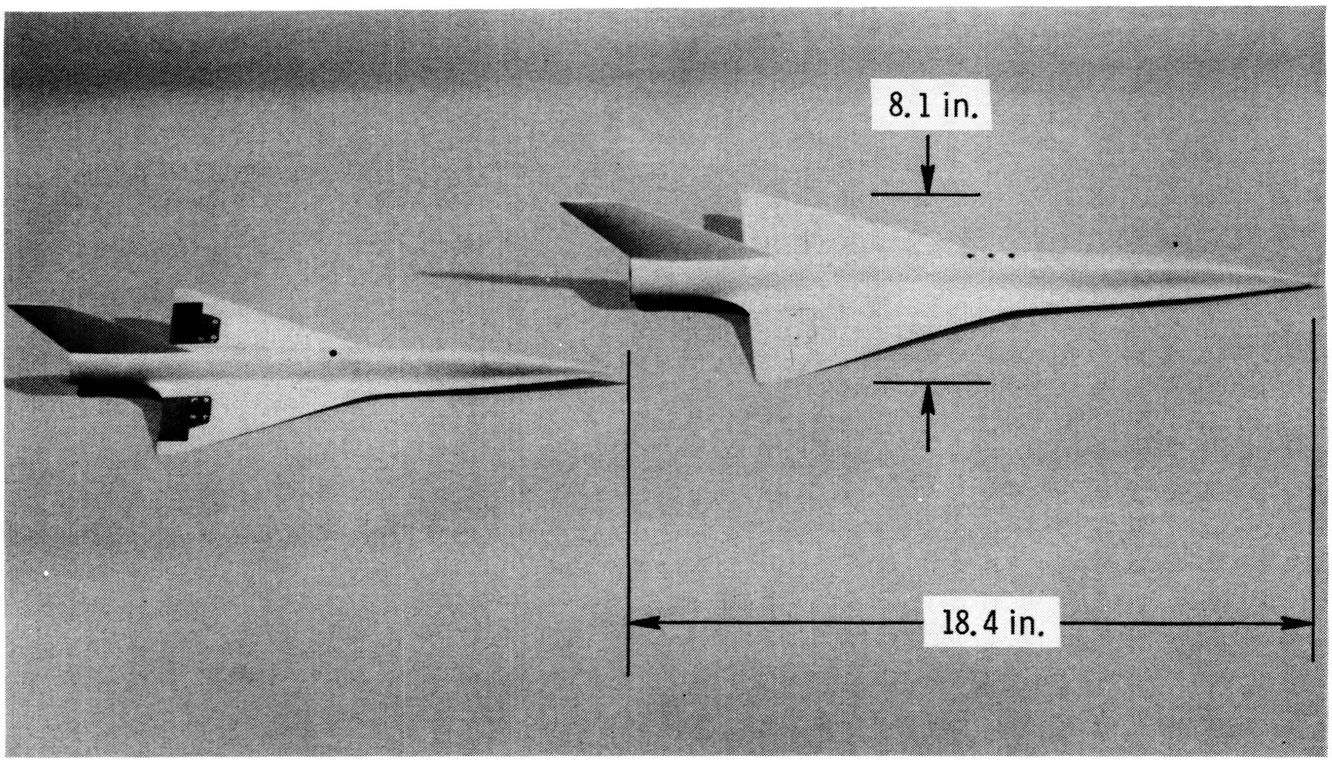
6- by 28-Inch TT Studies

Experimental studies on controlling the sidewall boundary layer in airfoil tests at transonic flow conditions via suction through a few discrete orifices have been initiated by Bill Sewall. The photograph shows a 3-inch-chord NACA 0012 model mounted on endplates for the 6- by 28-Inch Transonic Tunnel. Pressure orifices on the model upper surface are visible near midspan. Discrete sidewall orifices are seen on the endplate at the top of the photograph; each of these can be connected to either measure pressure or provide local sidewall boundary layer suction. The tubing stubs for this interchangeable connection are seen on the endplate at the bottom of the photograph; the tubing bundle is from the model upper-surface pressure orifices. The discrete endplate orifices are located along the model-endplate juncture, including one at the leading edge, and in the aft adverse pressure gradient region where shocks would form and tend to separate the sidewall boundary layer. The hardware has not yet been put into the tunnel.



HYPERSONIC MODELS USED IN SUBSCALE NTF INTERFERENCE EXPERIMENT

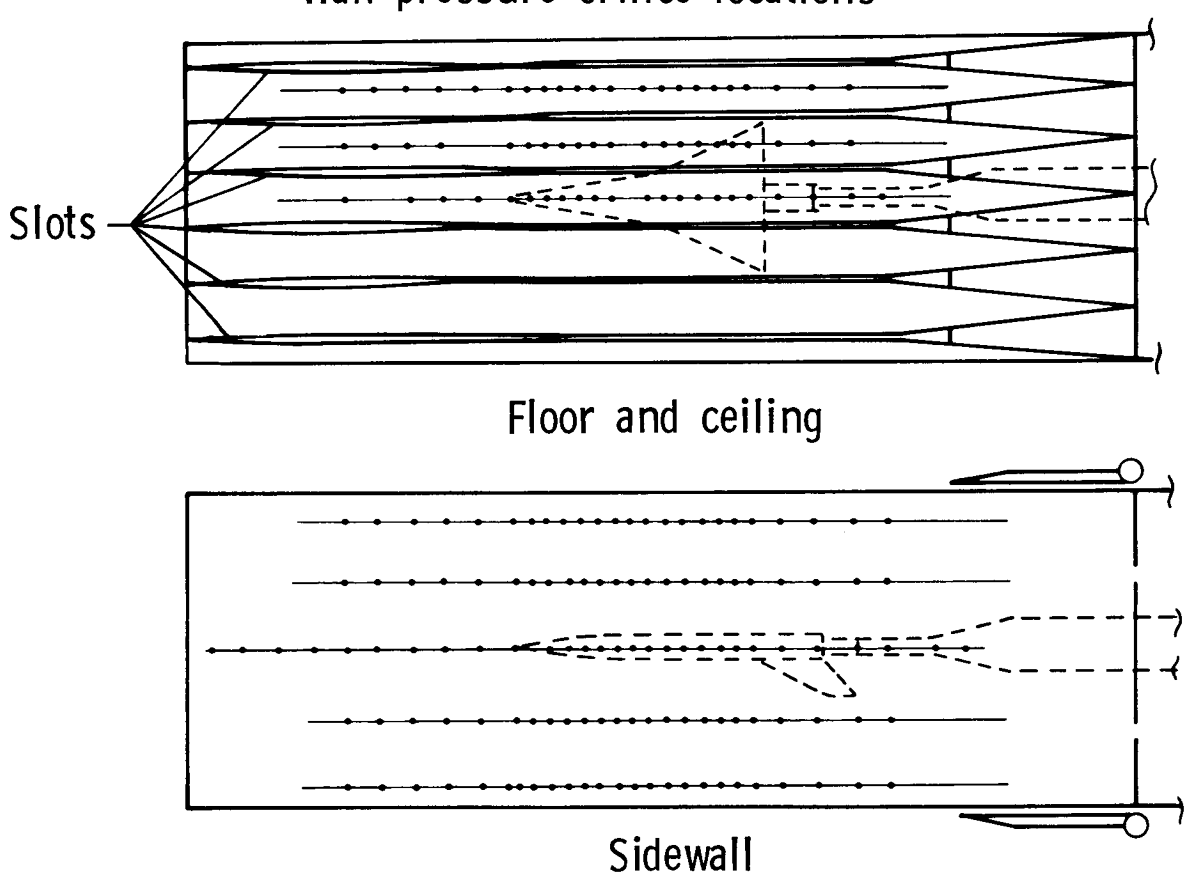
Three-dimensional transonic data bases suitable for testing and validating WIAC procedures are being taken on this pair of (previously existing) hypersonic models in a subscale NTF facility - the Diffuser Flow Apparatus (DFA). These models are the same shape but differ in size; some wall interference assessment can be made by comparing certain force and moment data between the two models. However, using the measured wall pressures as boundary data in a WIAC code, one would hope to get very similar corrected results independent of the model size. The differences caused by the inability to match the model Reynolds number at the same Mach number have been minimized by the selection of this configuration, which has a highly swept planform and a sharp nosed airfoil.



SUBSCALE NTF WITH LARGE HYPERSONIC MODEL

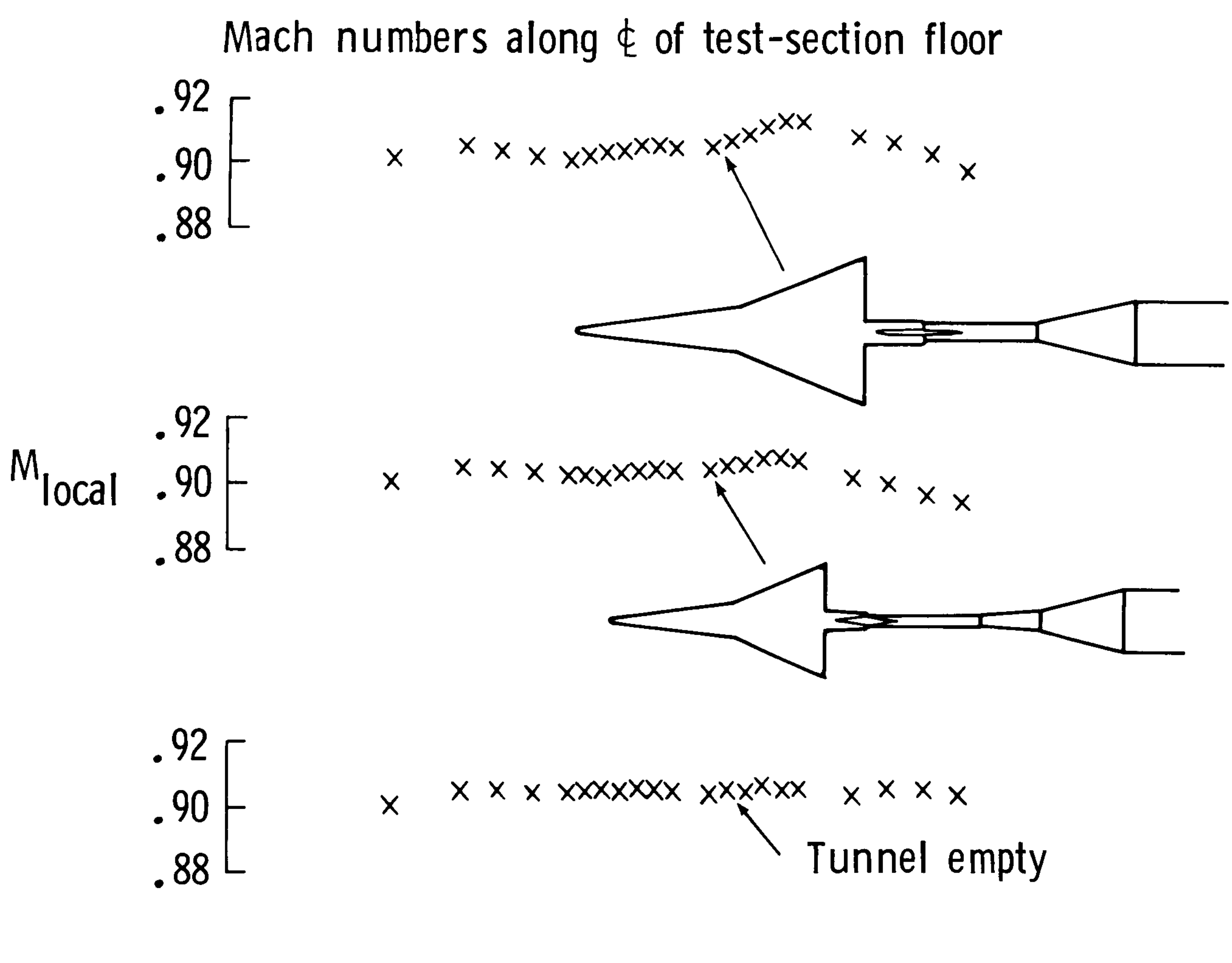
The wall pressure orifice layout on the DFA floor, ceiling, and sidewall is shown in this schematic. Location of these orifices with respect to the large hypersonic model, its supporting sting, the floor and ceiling wall slots, and reentry flaps can be seen. This particular pattern was determined by NTF slotted wall constraints and a linear theory wall interference code. The suitability of using data obtained with this particular orifice layout in existing 3-D linear and transonic simulation and WIAC codes is being analyzed at present. Another entry and additional testing is to be done in the DFA.

Wall pressure orifice locations



SUBSCALE NTF (DFA) SAMPLE RESULTS

Sample results for Mach number distributions along the centerline of the test section floor are given in the figure. These were for a nominal tunnel Mach number of 0.9 and at very-near-zero lift for both models. The tunnel was initially run empty, without either model or sting support system, to investigate the uniformity of the Mach number distribution in the test section and provide a Mach number calibration for the model tests. Wall Mach number signatures for both models are also shown; the influence of the sting flare can be seen downstream of the model location. This effect must be accounted for either in the WIAC procedure or by taking the sting signature out as a tare-type correction to the wall data. Tests of sting only have also been made.



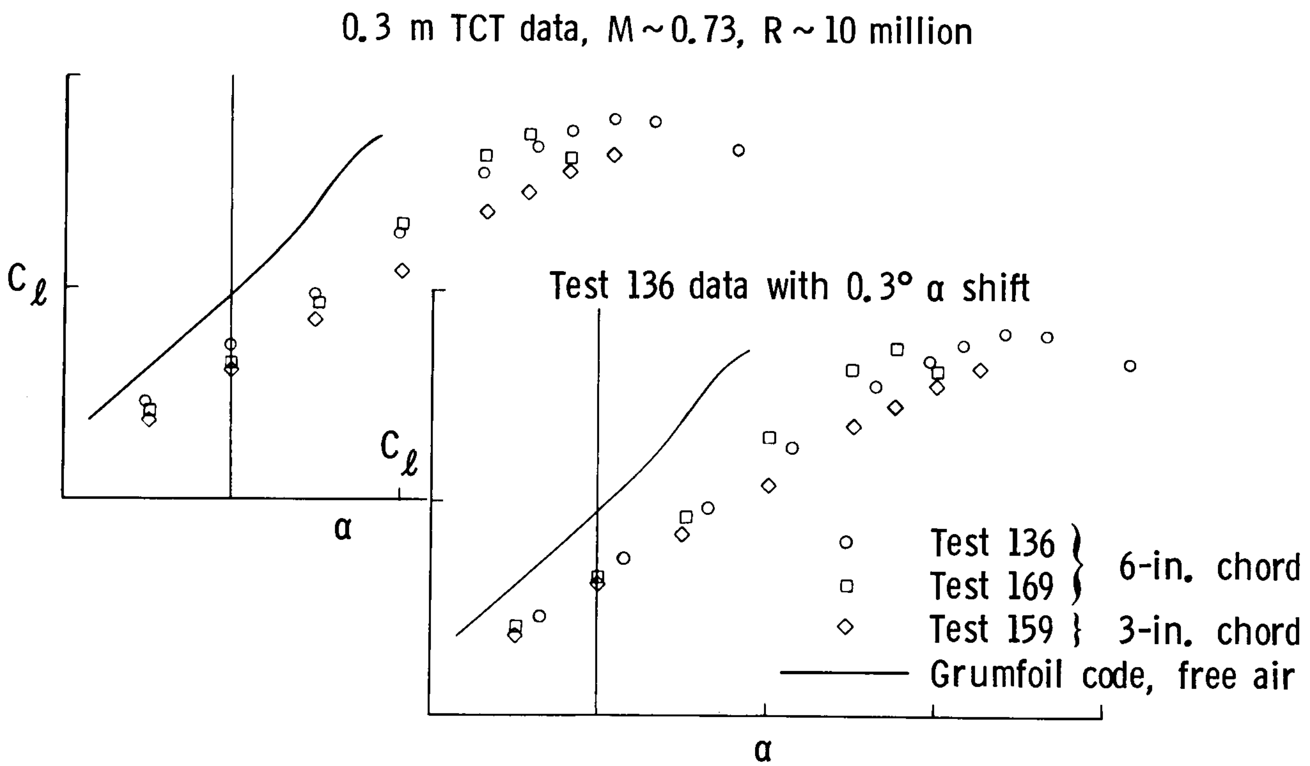
ASSESSMENT/CORRECTION PROCEDURES - WIAC

Wind tunnel wall interference assessment/correction (WIAC) procedures have evolved over the past decade; they are based upon ideas and capabilities from classical wall interference theory, adaptive wall concepts, and computational fluid dynamics. Specific representations have varied from classical-like pretest prediction methods to adaptive-like post-test correction methods; however, it is now generally believed that some flow-field data taken during the test are required in order to make an adequate assessment of or correction for transonic wall interference. The basic idea is to first numerically simulate the tunnel flow field, subject to measured boundary data, and then to search for a corresponding numerical solution in free air. Differences between such solutions are associated with wall interference corrections. When flight Mach and Reynolds numbers are both nearly matched in the tunnel test, then the corrections deduced by this correspondence may be valid well into the transonic flow regime. A nonlinear, transonic small-disturbance equation WIAC procedure has been developed for the airfoil test section of the 0.3-m TCT. It utilizes measured wall pressure data and accounts for interference from all four test section walls. For the NTF, both linear and nonlinear 3-D correction procedures are being developed. Nine longitudinal rows of wall pressure taps are being installed in the test section, and specific wall interference experiments are scheduled. Transonic nonpotential WIAC codes are being developed in order to determine the importance of nonisentropic effects in wall corrections.

- 0.3 m TCT, 8- by 24-inch airfoil TS
  - Wall pressure taps
  - Nonlinear, four-wall correction
  - Advanced technology airfoil test data
- NTF
  - Linear and nonlinear correction codes
  - Subscale NTF (DFA) data
  - Wall pressure taps being installed
  - Planned NTF wall interference tests
- Nonpotential WIAC code development
  - Flow Industries, Inc.
  - NCSU

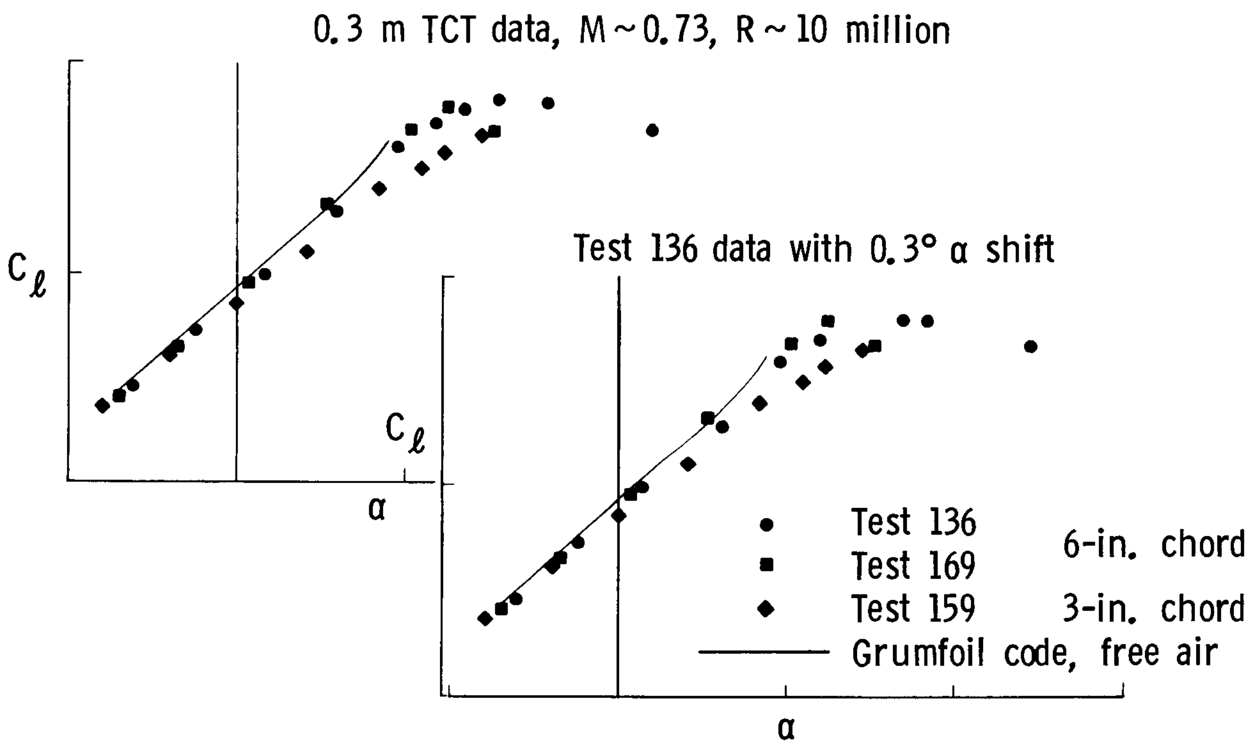
UNCORRECTED LIFT CURVES, CAST 10-2/DOA 2

A sample of wall interference corrections for airfoil data taken in the 8- by 24-inch test section of the 0.3-m TCT is given in the next two figures. These data were taken in cooperation with the DFVLR as part of NASA's Advanced Technology Airfoil Test program, in which U.S. industry also participated. On the left, uncorrected lift curve data from three tests (identified in the key) are compared with an independent free-air calculation from the GRUMFOIL 2-D transonic (full-potential equation with viscous interaction) airfoil code at the uncorrected tunnel conditions. Test 136 was run about 2 years prior to the other tests, and it was later deemed to have a -0.3° bias in the tunnel angle-of-attack. This bias has been accounted for and is the only difference in the figure on the right. It can be seen that the data are not collapsed in either case; furthermore, none agree with the free-air calculation.



FOUR WALL CORRECTED LIFT CURVES, CAST 10-2/DOA 2

The transonic airfoil WIAC procedure for the 8- by 24-inch test section of the 0.3-m TCT determines corrections for the tunnel Mach number and angle-of-attack. Corrections were obtained for some of the CAST 10-2/DOA 2 airfoil data before we realized that there was an angle-of-attack bias in one of the tests; these results are shown on the left. It can be seen that the corrected data are nearly collapsed and lie very close to the GRUMFOIL free-air results calculated at the corrected conditions. WIAC corrections were then made to the shifted Test 136 data, and these latter results are shown at the right. These results are essentially the same as those on the left, indicating that the WIAC procedure accounted for the bias automatically. In this procedure, the quoted tunnel Mach number and angle-of-attack are more properly only reference values.



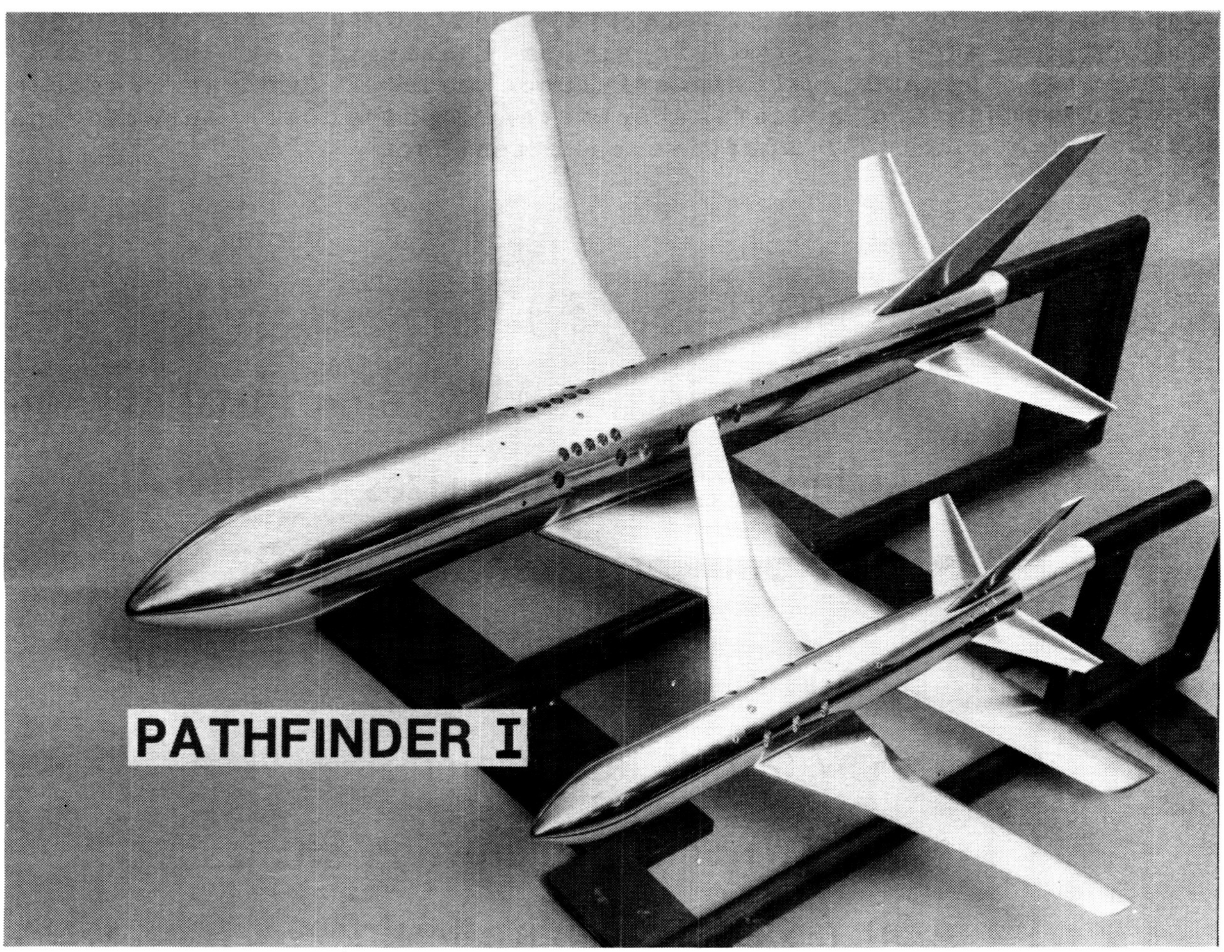
PLANNED NTF WALL INTERFERENCE EXPERIMENTS

NTF experiments specifically designed to study wall interference will be performed using several sizes of geometrically similar simple bodies of revolution and two sizes of Pathfinder I models. Both pointed and blunt bodies of revolution will be tested in order to study Reynolds number effects on blockage corrections and wave drag at Mach numbers near unity. The pointed bodies study will be directed toward very low supersonic flow conditions near maximum drag, whereas the blunt bodies, which are supercritical bodies of revolution, will be studied at very high subsonic flow conditions. Studies on the Pathfinder I model and a 1/2-scale Pathfinder I will evaluate combined blockage and lift interference on this general transport configuration. In all studies, tunnel wall pressures required by the wall interference assessment/correction procedures will be measured.

- Pointed bodies of revolution
- Blunt bodies of revolution
- Pathfinder I models

PATHFINDER I MODELS

An uninstrumented wing was fabricated to be tested on the Pathfinder I fuselage; this model will be used in conjunction with a 1/2-scale Pathfinder I model to evaluate the wall interference techniques for the NTF. Care was taken to assure that these two models were as geometrically and structurally similar as possible. Both of the wings were fabricated from the same material with the full-sized wing having a fabrication tolerance of ±0.004 inch and the 1/2-scale model having a fabrication tolerance of ±0.002 inch. Six-component strain-gauge balance data obtained from these models will be used in conjunction with static pressures measured on the test section floor, ceiling, and one sidewall to validate wall interference assessment/correction techniques for the NTF. The primary objective of these tests will be to study Reynolds and Mach number effects on combined blockage and lift interference at high subsonic flow conditions appropriate to transport configurations.



ADAPTIVE WALL TECHNOLOGY - FLEXIBLE

The adaptive wall test section concept, using solid flexible walls, attempts to reduce or eliminate wall interference while providing a boundary condition more suitable for mathematical analysis than that of the ventilated wall concepts. Therefore, contouring the solid walls of the test section along free-air streamlines is the basis of the adaptive wall test section concept being pursued at Langley and the University of Southampton under an NASA grant. The concept uses a wind tunnel together with the high-speed digital computer. Both the wind tunnel and the computer are used to provide a part of the total flow field, each working in the region best suited to its unique capability. That is, the tunnel solves the real, viscous, rotational, inner flow field about the model, while the computer solves the imaginary outer flow field extending to infinity. An adaptive wall test section configured for 2-D testing is being installed in the 0.3-m Transonic Cryogenic Tunnel (TCT) circuit. The design of this test section is based upon the work undertaken at Southampton. The self-streamlining wall test section (SSW TS) of the 0.3-m TCT is 13 by 13 inches, whereas that of the transonic self-streamlining wall tunnel (TSSWT) at Southampton is 6 by 6 inches. Initial airfoil tests in the 0.3-m TCT will be for models in two sizes; early attempts at 3-D testing in it will use the AEDC wall interference model. Current research studies at Southampton concern shockwave/adaptive wall interaction control and 3-D model/2-D adaptive wall testing.

- 0.3 m TCT (NASA Langley)
    - 13- by 13-inch SSW TS being installed
    - Airfoil models in two sizes initially
    - AEDC wall interference model for 3D
- TSSWT (Univ. of Southampton)
    - 6- by 6-inch test section
    - Shockwave/wall interaction studies
    - 3D model/2D adaptive testing

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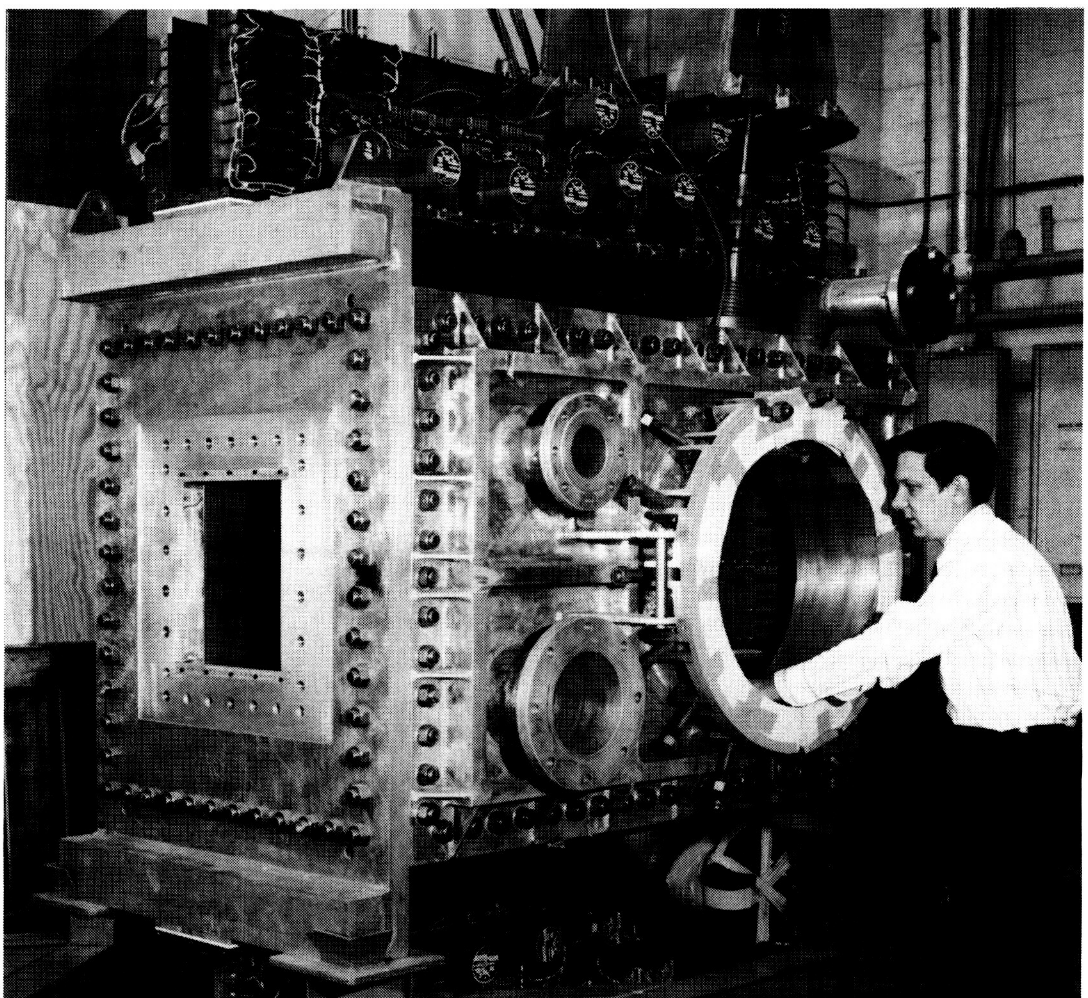
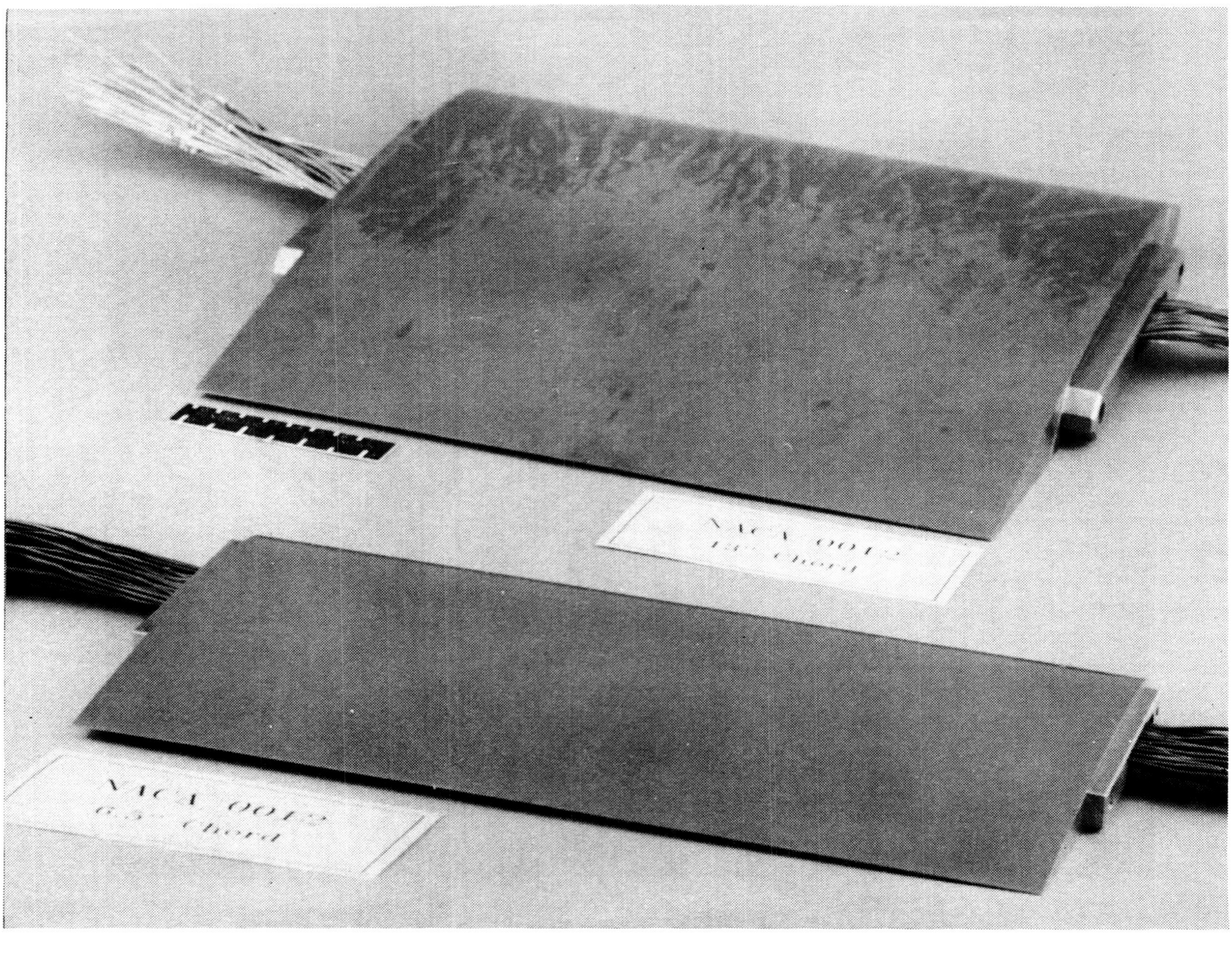
13- by 13-INCH SELF STREAMLINING WALL TEST SECTION, 0.3-M TCT

The 13- by 13-inch self streamlining wall test section is now being installed in the 0.3-m TCT. This new test section, shown in the photograph, is configured for two-dimensional testing. The test section is 56 inches long, and all four walls are solid with the top and bottom walls being flexible. Stepping motors, which drive the wall jacks, can be seen at the top and bottom of the photograph. Models with chords up to 13 inches can be tested over an angle-of-attack range of ±20 degrees. Windows located in the top portion of the turntable allow limited viewing of the region above the model. A traversing mechanism may be installed at several downstream locations. One of the plates for the optional sidewall boundary-layer removal system is barely visible through the test section access port.



AIRFOIL MODELS IN TWO SIZES

Initial tests in the 13- by 13-inch SSW TS of the 0.3-m TCT will be for tunnel systems checkout, performance, flow quality, and wall adaptation to uniform flow at various conditions. Upon completion of these initial tests, two tests of airfoil pairs are scheduled to determine the operational capabilities of the adaptation software and to investigate 2-D wind tunnel wall interference at high Reynolds numbers. Two NACA 0012 airfoil models, one with a 6.5-inch chord and the other with a 13-inch chord, as shown in the photograph, will be tested to assess the software at values of tunnel height to model chord down to 1.0. The results from these tests can be compared with results from tests of the NACA 0012 in the 0.3-m TCT and other facilities. Two joint cooperative programs, one an NASA/ONERA/DFVLR effort and the other an NASA/NAE effort, have been established to test DOA CAST-10 airfoil models of 7- and 9-inch chords, respectively. These joint data will be used to assess the effects of model manufacturing differences and to compare the results on the same airfoil model in different facilities.



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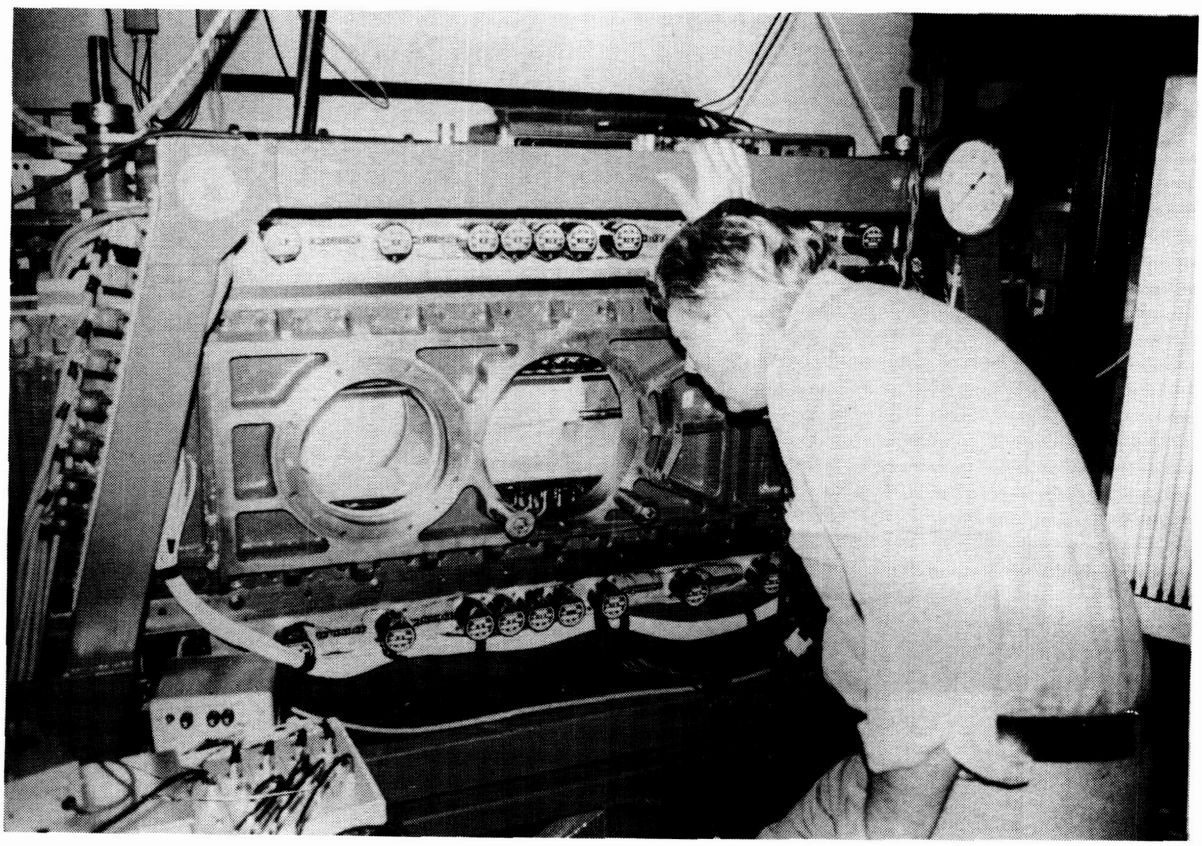
TRANSONIC SELF STREAMLINING WALL TUNNEL

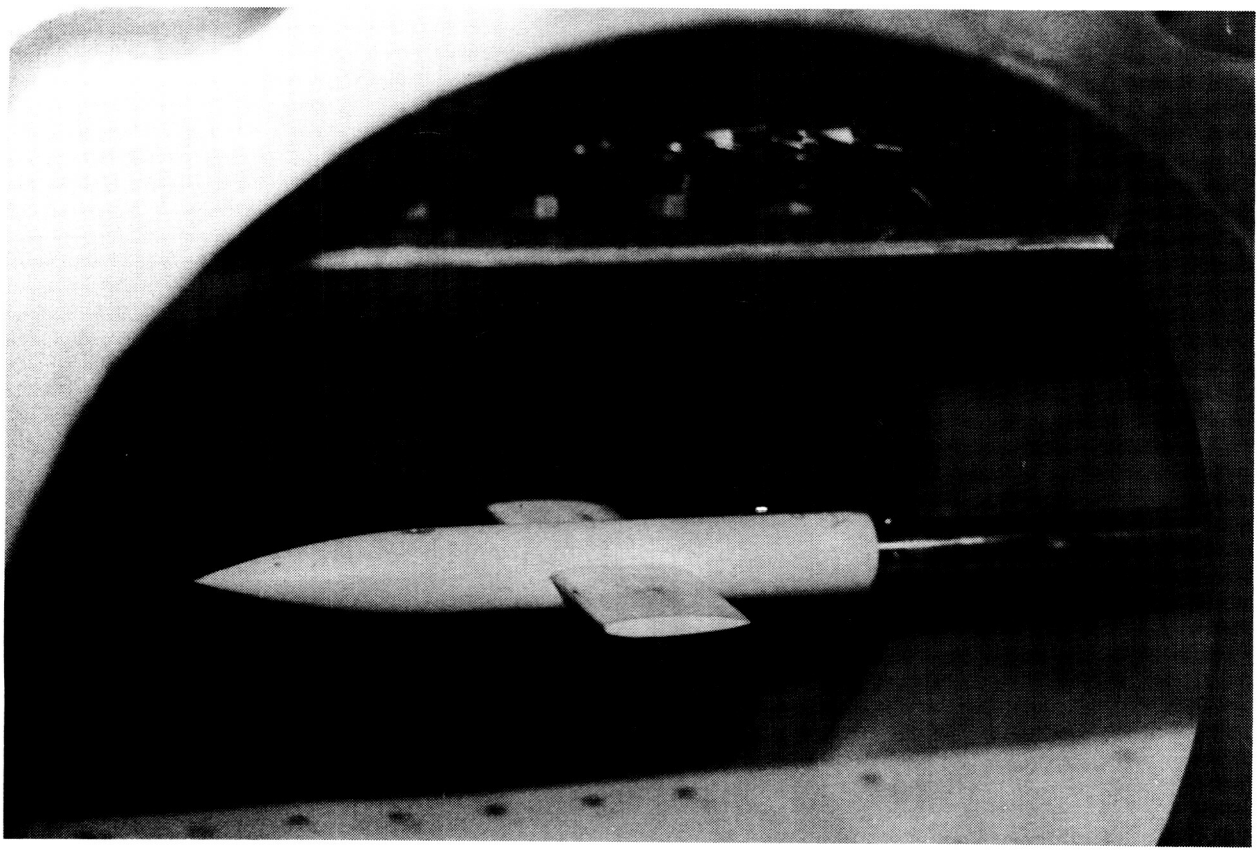
University of Southampton

Adaptive wall work at the University of Southampton under NASA Langley sponsorship has been going on for a little more than a decade. Recent accomplishments include successful transonic testing of airfoils down to tunnel height-to-chord ratios of about one and at flow conditions where the supercritical flow region extends to the adapted walls. The facility is automated and has a reasonably rapid response. Good agreement has been seen between results from the TSSWT and several other 2-D adaptive flexible wall tunnels. Current 2-D research is toward use through Mach numbers of unity. Initial research on 3-D model testing within 2-D adaptable walls has also begun. The photograph shows a 3-D model mounted in the University of Southampton TSSWT.



3-D MODEL/2-D WALL ADAPTATION

The 3-D model is viewed here through the access port of the TSSWT as shown on the previous photograph. The edge of the 2-D flexible wall above the model is also seen through the port. Here, the goal of testing free from wall interference cannot be met. The philosophy adopted is to provide the test section with sufficient static pressure taps around and along its length to allow various measures of interference to be quantified. The principal interferences that the model experiences are wall-induced velocities in the streamwise and vertical directions. This induced velocity field can be manipulated by 2-D wall movement, and hence the level of interference can be reduced. Assessment of and correction for residual interference will be made using the wall pressure and location data measured for the final 2-D adapted wall setting in a given test run.



A DECADE OF RENEWED WIND TUNNEL WALL INTERFERENCE RESEARCH

This last chart characterizes NASA Langley's recently renewed wind tunnel wall interference research. In addition to the points listed, it should be added that most of our wall interference research to date has been directed toward conventional slotted-wall transonic tunnels; solid, flexible, adaptive-wall, transonic tunnels; and assessment/correction methods related to them. The publications list does not include work related to high-lift (V/STOL), supersonic-hypersonic, and unsteady wall interference research, which have also been pursued during this past decade at Langley. Furthermore, one should not assume from the number of researchers listed on the publications that our transonic effort is a large one; few are full-time wall interference players. One tends to become interested in transonic wall interference only when a promising new idea comes along or when all other explanations fail in trying to understand the test results.

- NASA Langley focus is transonic flow
- Both analytical and experimental aspects being pursued
- Applications for prediction, assessment/correction, avoidance, and verification continue
- Work best summarized by publications (list in handout)

A DECADE OF RENEWED NASA LANGLEY SPONSORED TRANSONIC WIND TUNNEL WALL INTERFERENCE RESEARCH

I. GENERAL

A. Wall Interference

1. Kemp, W. B., Jr.: Transonic Wind-Tunnel Wall Interference. NASA CP-2009, 1977, pp. 65-71.

2. Pierpont, P. K. (editor): Advanced Technology Airfoil Research. NASA CP-2045, 1979.

3. Newman, P. A.; and Kemp, W. B., Jr.: Wall-Interference Effects: Status Review and Planned Experiments in NTF. NASA CP-2183, 1981, pp. 123-141.

4. South, J. C., Jr.; and Thames, F. C.: Report of the Panel on Theoretical Aerodynamics. NASA CP-2183, 1981, pp. 277-286.

5. McKinney, L. W.; and Baals, D. D. (editors): Wind-Tunnel/Flight Correlation - 1981. NASA CP-2225, 1982.

6. Tuttle, M. H.; and Plentovich, E. B.: Adaptive Wall Wind Tunnels, A Selected, Annotated Bibliography. NASA TM-84526, 1982.

7. Newman, P. A.; and Barnwell, R. W. (editors): Wind Tunnel Wall Interference Assessment/Correction - 1983. NASA CP-2319, 1984.

8. Bobbitt, P. J.; and Newman, P. A.: Discussion of Wind Tunnel Wall Interference Correction Issues. NASA CP-2319, 1984, pp. 415-423.

9. Gloss, B. B.: Initial Research Program for the National Transonic Facility. AIAA Paper 84-0585, 1984.

B. Langley Facilities

1. Goodyer, M. J.; and Kilgore, R. A.: High Reynolds Number Cryogenic Wind Tunnel. AIAA Paper 72-995, 1972. (AIAA J., vol. 11, no. 5, 1973, pp. 613-619).

2. Kilgore, R. A.; Adcock, J. B.; and Ray, E. J.: Flight Simulation Characteristics of the Langley High Reynolds Number Cryogenic Transonic Tunnel. AIAA Paper 72-80, 1972. (J. Aircraft, vol. 11, no. 10, 1974).

3. Ladson, C. L.: Description and Calibration of the Langley 6- by 9-Inch Transonic Tunnel. NASA TN D-7182, 1973.

4. Kilgore, R. A.; Goodyer, M. J.; Adcock, J. B.; and Davenport, E. E.: The Cryogenic Wind-Tunnel Concept for High Reynolds Number Testing. NASA TN D-7762, 1974.

5. Ray, E. J; Kilgore, R. A.; Adcock, J. B.; and Davenport, E. E.: Test Results From the Langley High Reynolds Number Cryogenic Transonic Tunnel. AIAA Paper 74-631, 1974.

6. Ladson, C. L.: Description and Calibration of the Langley 6- by 28-Inch Transonic Tunnel. NASA TN D-8070, 1975.

7. McKinney, L. W.; and Howell, R. R.: The Characteristics of the Planned National Transonic Facility. Proceedings AIAA Ninth Aerodynamic Testing Conference, 1976, pp. 176-184.

8. Howell, R. R.; and McKinney, L. W.: The U.S. 2.5-Meter Cryogenic High Reynolds Number Tunnel. ICAS Paper 76-04, 1976.

9. Baals, D. D.: Design Considerations of the National Transonic Facility. NASA CP-2001, 1976, pp. 1583-1602.

10. Kilgore, R. A.: Design Features and Operational Characteristics of the Langley 0.3-Meter Transonic Cryogenic Tunnel. NASA TN D-8304, 1976.

11. Baals, D. D. (Editor): High Reynolds Number Research. NASA CP-2009, 1977.

12. Nicks, O. W.; and McKinney, L. W.: Status and Operational Characteristics of the National Transonic Facility. AIAA Paper 78-770, 1978.

13. Kilgore, R. A.; Igoe, W. B.; Adcock, J. B.; Hall, R. M.; and Johnson, C. B.: Full Scale Aircraft Simulation with Cryogenic Tunnels and Status of the National Transonic Facility. NASA TM-80085, 1979.

14. Ray, E. J.; Ladson, C. L.; Adcock, J. B.; Lawing, P. L.; and Hall, R. M.: Review of Design and Operational Characteristics of the 0.3-Meter Transonic Cryogenic Tunnel. NASA TM-80123, 1979.

15. Kilgore, R. A.: Development of the Cryogenic Tunnel Concept and Application to the U.S. National Transonic Facility. AGARD-AG-240, 1979, pp. 2-1 to 2-27.

16. Ray, E. J.: Langley's Two-Dimensional Research Facilities - Capabilities and Plans. NASA CP-2045, 1979, pp. 399-414.

17. Howell, R. R.: The National Transonic Facility: Status and Operational Planning. AIAA Paper 80-0415, 1980.

18. Ladson, C. L.; and Kilgore, R. A.: Instrumentation for Calibration and Control of a Continuous-Flow Cryogenic Tunnel. NASA TM-81825, 1980.

19. Igoe, W. B.: Characteristics and Status of the U.S. National Transonic Facility. AGARD Lecture Series No. 111, 1980.

20. Gloss, B. B.; and Nystrom, D.: Estimation of Fan Pressure Ratio Requirements and Operating Performance for the National Transonic Facility. NASA TM-81802, 1981.

21. Sewall, W. G.: Description of Recent Changes in the Langley 6- by 28-Inch Transonic Tunnel. NASA TM-81947, 1981.

22. McKinney, L. W.; and Baals, D. D. (Editors): High Reynolds Number Research - 1980. NASA CP-2183, 1981.

23. Fuller, D. E.: Guide for Users of the National Transonic Facility. NASA TM-83124, 1981.

24. Polhamus, E. C.: The Large Second Generation of Cryogenic Tunnels. Astronautics and Aeronautics Magazine, Oct. 1981, pp. 38-51.

25. McKinney, L. W.; and Gloss, B. B.: Status of the National Transonic Facility. AIAA Paper 82-0604, 1982.

26. McKinney, L. W.: Operational Experience with the National Transonic Facility. AGARD-CP-348, 1984, pp. 1-1 to 1-8.

27. Bruce, W. E., Jr.; Fuller, D. E.; and Igoe, W. B.: National Transonic Facility Shakedown Test Results and Calibration Plans. AIAA Paper 84-0584, 1984.

28. McGhee, R. J.; Beasley, W. D.; and Foster, J. M: Recent Modifications and Calibration of the Langley Low-Turbulence Pressure Tunnel. NASA TP-2328, 1984.

29. Campbell, J. F.: The National Transonic Facility - A Research Perspective. AIAA Paper 84-2150, 1984.

Unpublished:

30. National Transonic Facility Research Symposium, NASA Langley Research Center, Dec. 5, 1983 (viewgraphs only).

II. BASIC

A. Slotted Walls

1. Mann, M. J.: Low-Speed Upwash Interference on a Transport Model in a Rectangular Slotted-Wall Wind Tunnel. NASA TM X-3218, 1975.

2. Barnwell, R. W.: Improvements in the Slotted-Wall Boundary Condition. Proceedings AIAA Ninth Aerodynamic Testing Conference, 1976, pp. 21-30.

3. Barnwell, R. W.: Design and Performance Evaluation of Slotted Walls for Two-Dimensional Wind Tunnels. NASA TM-78648, 1978.

4. Everhart, J. L.; and Barnwell, R. W.: A Parametric Experimental Study of the Interference Effects and the Boundary-Condition Coefficient of Slotted Wind-Tunnel Walls. AIAA Paper 78-805, 1978.

5. Barnwell, R. W.; Sewall, W. G.; and Everhart, J. L.: Design and Calibration of Slotted Walls for Transonic Airfoil Wind Tunnels. NASA CP-2045, 1979, pp. 433-443.

6. Everhart, J. L.; and Barnwell, R. W.: A Parametric Experimental Study of the Slotted-Wall Boundary Condition. NASA CP-2045, 1979, pp. 459-471.

7. Ramaswamy, M. A.; and Cornette, E. S.: Supersonic Flow Development in Slotted Wall Tunnels. AIAA Paper 80-0443, 1980. (AIAA J., vol. 20, no. 6, 1982, pp. 805-811).

8. Barger, R. L.: A Theory for Predicting Boundary Impedance and Resonant Frequencies of Slotted-Wall Wind Tunnels, Including Plenum Effects. NASA TP-1880, 1981.

9. Everhart, J. L.: Potential Flow Through a Cascade of Alternately Displaced Circular Bodies - The Rod-Wall Wind-Tunnel Boundary Condition. NASA TM-85750, 1984.

B. Sidewall Boundary Layers

1. Barnwell, R. W.: A Similarity Rule for Compressibility and Sidewall Boundary Layer Effects in Two-Dimensional Wind Tunnels. AIAA Paper 79-108, 1979. (AIAA J., vol. 18, no. 9, 1980, pp. 1149-1151).

2. Sewall, W. G.: The Effects of Sidewall Boundary Layers in Two-Dimensional Subsonic and Transonic Wind Tunnels. AIAA Paper 81-1297, 1981. (AIAA J., vol. 20, no. 9, 1982, pp. 1253-1256).

3. Murthy, A. V.; Johnson, C. B.; Ray, E. J.; and Lawing, P. L.: Recent Sidewall Boundary-Layer Investigations with Suction in the Langley 0.3-m Transonic Cryogenic Tunnel. AIAA Paper 82-0234, 1982.

4. Barnwell, R. W.; and Sewall, W. G.: Similarity Rules for Effects of Sidewall Boundary Layer in Two-Dimensional Wind Tunnels. AGARD-CP-335, 1982, pp. 3-1 to 3-10.

5. Sewall, W. G.: Application of a Transonic Similarity Rule to Correct the Effects of Sidewall Boundary Layers in Two-Dimensional Transonic Wind Tunnels. NASA TM-84847, 1982.

6. Adcock, J. B.; and Barnwell, R. W.: Effect of Boundary Layers on Solid Walls in Three-Dimensional Subsonic Wind Tunnels. AIAA Paper 83-0144, 1983. (AIAA J., vol. 22, no. 3, 1984, pp. 365-371).

7. Murthy, A. V.; Johnson, C. B.; Ray, E. J.; Lawing, P. L.; and Thibodeaux, J. J.: Investigation of Upstream Sidewall Boundary Layer Removal Effects on a Supercritical Airfoil. AIAA Paper 83-0386, 1983.

8. Murthy, A. V.; Johnson, C. B.; Ray, E. J.; Lawing, P. L.; and Thibodeaux, J. J.: Studies of Sidewall Boundary Layer in the Langley 0.3-Meter Transonic Cryogenic Tunnel With and Without Suction. NASA TP-2096, 1983.

9. Johnson, C. B.; Murthy, A. V.; Ray, E. J.; Lawing, P. L.; Thibodeaux, J. J.: Effect of Upstream Sidewall Boundary Layer Removal on an Airfoil Test. NASA CP-2319, 1984, pp. 143-163.

10. Adcock, J. B.; and Barnwell, R. W.: Effect of Boundary Layers on Solid Walls in Three-Dimensional Subsonic Wind Tunnels. NASA CP-2319, 1984, pp. 205-218.

11. Jenkins, R. V.: Some Experience With Barnwell-Sewall Type Correction to Two-Dimensional Airfoil Data. NASA CP-2319, 1984, pp. 375-392.

12. Barnwell, R. W.: Effect of Sidewall Suction on Flow in Two-Dimensional Wind Tunnels, AIAA Paper 84-0242, 1984.

13. Murthy, A. V.; Johnson, C. B.; Ray, E. J.; and Stanewsky, E.: Investigation of Sidewall Boundary Layer Removal Effects on Two Different Chord Airfoil Models in the Langley 0.3-Meter Transonic Cryogenic Tunnel. AIAA Paper 84-0598, 1984.

14. Murthy, A. V.: Corrections for the Attached Sidewall Boundary-Layer Effects in Two-Dimensional Airfoil Testing. NASA CR-3873, 1985.

C. Data Bases (With Measured Wall Pressures)

1. Couch, L. M.: Transonic Wall Interference Effects on Bodies of Revolution. AIAA Paper 72-1008, 1972.

2. Couch, L. M.; and Brooks, C. W., Jr.: Effect of Blockage Ratio on Drag and Pressure Distributions for Bodies of Revolution at Transonic Speeds. NASA TN D-7331, 1973.

3. Blackwell, J. A., Jr.; Burdges, K. P.; and Hinson, B.: Effect of Wall Porosity on a NASA 10% Thick Supercritical Airfoil at Transonic Speeds. NASA CR-132712, 1975.

4. Blackwell, J. A., Jr.; and Pounds, G. A.: Wind-Tunnel Wall Interference Effects on a Supercritical Airfoil at Transonic Speeds. J. Aircraft, vol. 14, no. 10, 1977, pp. 929-935. (Also Proceedings AIAA Ninth Aerodynamic Testing Conference, 1976, pp. 1-11.)

5. Baronti, P.; and Roffe, G.: An Experimental Investigation of a Transonic Interference Over a Three-Dimensional Wing. General Applied Science Laboratories, Inc., TR No. 244, 1977.

6. Ladson, C. L.; and Ray, E. J.: Status of Advanced Airfoil Tests in the Langley 0.3-Meter Transonic Cryogenic Tunnel. NASA CP-2208, 1981, pp. 37-53.

7. Wolf, S. W. D.: Model and Boundary Aerodynamic Data From High Blockage Two-Dimensional Airfoil Tests in a Shallow Unstreamlined Transonic Flexible Walled Test Section. NASA CR-165685, 1981.

8. Johnson, W. G., Jr.; Hill, A. S.; Ray, E. J.; Rozendaal, R. A.; and Butler, T. W.: High Reynolds Number Tests of a Boeing BAC I Airfoil in the Langley 0.3-Meter Transonic Cryogenic Tunnel. NASA TM-81922, 1982.

9. Reaser, J. S.: Transonic Testing in a Cryogenic 2-D Wind Tunnel of an Advanced Technology Airfoil. Lockheed-California, Burbank, Report No. LR-30047, 1982.

10. Ray, E. J.: A Review of Reynolds Number Studies Conducted in the Langley 0.3-m Transonic Cryogenic Tunnel. AIAA Paper 82-0941, 1982.

11. Dress, D. A.; Johnson, C. B.; McGuire, P. D.; Stanewsky, E.; and Ray, E. J.: High Reynolds Number Tests of the CAST 10-2/DOA 2 Airfoil in the Langley 0.3-Meter Transonic Cryogenic Tunnel - Phase I. NASA TM-84620, 1983.

12. Reaser, J. S.; Hallissy, J. B.; and Campbell, R. L.: Design and True Reynolds Number 2-D Testing of an Advanced Technology Airfoil. AIAA Paper 83-1792, 1983.

13. Reaser, J. S.: Testing of an Advanced Technology Transonic Airfoil in a 2-D Cryogenic Wind Tunnel. Lockheed-California, Burbank, Report No. LR-30418, 1983.

14. Jenkins, R. V.: Tabulation of Data From Tests of an NPL 9510 Airfoil in the Langley 0.3-Meter Transonic Cryogenic Tunnel. NASA TM-84579, 1983.

15. Jenkins, R. V.: Reynolds Number Tests of an NPL 9510 Airfoil in the Langley 0.3-Meter Transonic Cryogenic Tunnel. NASA TM-85663, 1983.

16. Stanewsky, E.; Demurie, F.; Ray, E. J.: and Johnson, C. B.: High Reynolds Number Tests of the CAST 10-2/DOA 2 Transonic Airfoil at Ambient and Cryogenic Temperature Conditions. AGARD-CP-348, 1984, pp. 10-1 to 10-13.

17. Plentovich, E. B.; Ladson, C. L.; and Hill, A. S.: Tests of a NACA 65_1-213 Airfoil in the NASA Langley 0.3-Meter Transonic Cyrogenic Tunnel. NASA TM-85732, 1984.

18. Sewall, W. G.: Wall Pressure Measurements for Three-Dimensional Transonic Tests. AIAA Paper 84-0599, 1984.

19. Dress, D. A.; Stanewsky, E.; McGuire, P. D.; and Ray, E. J.: High Reynolds Number Tests of the CAST 10-2/DOA 2 Airfoil in the Langley 0.3-Meter Transonic Cryogenic Tunnel - Phase II. NASA TM-86273, 1984.

20. Jenkins, R. V.; Johnson, W. G., Jr.; Hill, A. S.; Mueller, R.; and Redeker, G.: Data From Tests of an R4 Airfoil in the Langley 0.3-Meter Transonic Cryogenic Tunnel. NASA TM-85739, 1984.

21. Ray, E. J.; and Ladson, C. L.: Review of the Advanced Technology Airfoil Test Program in the 0.3-M Transonic Cryogenic Tunnel. NASA CP-2319, 1984, pp. 361-373.

22. Johnson, W. G., Jr.; Hill, A. S.; and Eichmann, O.: Pressure Distributions from High Reynolds Number Tests of a NASA SC(3)-0712(B) Airfoil in the Langley 0.3-Meter Transonic Cryogenic Tunnel. NASA TM-86370, 1985.

23. Johnson, W. G., Jr.; Hill, A. S.; and Eichmann, O.: High Reynolds Number Tests of a NASA SC(3)-0712(B) Airfoil in the Langley 0.3-Meter Transonic Cryogenic Tunnel. NASA TM-86371, 1985.

D. Simulator Codes

1. Barnwell, R. W.: Transonic Flow About Lifting Wing-Body Combinations. AIAA Paper 74-185, 1974.

2. Newman, P. A.; and Klunker, E. B.: Numerical Modeling of Tunnel-Wall and Body-Shape Effects on Transonic Flows Over Finite Lifting Wings. NASA SP-347, 1975, pp. 1189-1212.

3. Barnwell, R. W.: Approximate Method for Calculating Transonic Flow About Lifting Wing Body Combinations. NASA SP-347, 1975, pp. 1281-1303.

4. South, J. C., Jr.; and Keller, J. D.: Axisymmetric Transonic Flow Including Wind Tunnel Wall Effects. NASA SP-347, 1975, pp. 1233-1267.

5. Ruger, C.; and Baronti, P.: A Linear Solution of Lift Interference in Square Tunnels With Slotted Test Sections of Finite Length. NASA CR-144980, 1975.

6. Doria, M. L.; and South, J. C., Jr.: Transonic Potential Flow and Coordinate Generation for Bodies in a Wind Tunnel. AIAA Paper 82-0223, 1982.

7. Wedan, B.; and South, J. C., Jr.: A Method for Solving the Transonic Full-Potential Equation for General Configurations. AIAA 83-1889, 1983.

8. Kemp, W. B., Jr.: An Interference Assessment Approach for a Three-Dimensional Slotted Tunnel With Sparse Wall Pressure Data. NASA CP-2319, 1984, pp. 323-334.

9. Kemp, W. B., Jr.: A Slotted Test Section Numerical Model for Interference Assessment. AIAA Paper 84-0627, 1984. (J. Aircraft, vol. 22, no. 3, 1985, pp. 216-222).

10. South, J. C., Jr.; Doria, M. L.; and Green, L. L.: Finite-Volume Scheme for Transonic Potential Flow About Airfoils and Bodies in an Arbitrarily-Shaped Channel. Third Symposium on Numerical and Physical Aspects of Aerodynamic Flows, 1985.

III. WIAC

1. Kemp, W. B., Jr.: Toward the Correctable-Interference Transonic Wind Tunnel. Proceedings AIAA Ninth Aerodynamic Testing Conference, 1976, pp. 31-38.

2. Kemp, W. B., Jr.: Transonic Assessment of Two-Dimensional Wind Tunnel Wall Interference Using Measured Wall Pressures. NASA CP-2045, 1979, pp. 473-486.

3. Blackwell, J. A.: Wind-Tunnel Blockage Correction for Two-Dimensional Transonic Flow. J. Aircraft, vol. 16, no. 4, 1979, pp. 256-263.

4. Kemp, W. B., Jr.: TWINTAN: A Program for Transonic Wall Interference Assessment in Two-Dimensional Wind Tunnels. NASA TM-81819, 1980.

5. Rizk, M. H.: A New Optimization Technique Applied to Wind Tunnel Angle-of-Attack Corrections. Flow Research Company Note No. 198, 1982.

6. Kemp, W. B., Jr.; and Adcock, J. B.: Combined Four-Wall Interference Assessment in Two-Dimensional Airfoil Tests. AIAA Paper 82-0586, 1982. (AIAA J., vol. 21, no. 10, 1983, pp. 1353-1359).

7. Rizk, M. H.; Hafez, M.; Murman, E. M.; and Lovell, D.: Transonic Wind Tunnel Wall Interference Corrections for Three-Dimensional Models. AIAA Paper 82-0588, 1982.

8. Rizk, M. H.; and Smithmeyer, M. G.: Wind-Tunnel Wall Interference Corrections for Three-Dimensional Flows. J. Aircraft, vol. 19, no. 6, 1982, pp. 465-472.

9. Rizk, M. H.: Higher-Order Flow Angle Corrections for Three-Dimensional Wind Tunnel Wall Interference. J. Aircraft, vol. 19, no. 10, 1982, pp. 893-895.

10. Gopinath, R.: Wall Interference Evaluation from Pressure Measurement on Control Surfaces. J. Aircraft, vol. 19, no. 12, 1982, pp. 1097-1098.

11. Rizk, M. H.: A New Approach to Optimization for Aerodynamic Applications. J. Aircraft, vol. 20, no. 1, 1983, pp. 94-96.

12. Rizk, M. H.: The Single-Cycle Scheme: A New Approach to Numerical Optimization. AIAA J., vol. 21, no. 12, 1983, pp. 1640-1647.

13. Rizk, M. H.; and Murman, E. M.: Wind Tunnel Wall Interference Corrections for Aircraft Models in the Transonic Regime. J. Aircraft, vol. 21, no. 1, 1984, pp. 54-61.

14. Kemp, W. B., Jr.: TWINTN4: A Program for Transonic Four-Wall Interference Assessment in Two-Dimensional Wind Tunnels. NASA CR-3777, 1984.

15. Rizk, M. H.; Smithmeyer, M. G.; and Murman, E. M.: Wind Tunnel Wall Interference Corrections for Aircraft Models. NASA CP-2319, 1984, pp. 301-322.

16. Gumbert, C. R.; Newman, P. A.; Kemp, W. B., Jr.; and Adcock, J. B.: Adaptation of a Four-Wall Interference Assessment/Correction Procedure for Airfoil Tests in the 0.3-m TCT. NASA CP-2319, 1984, pp. 393-411.

17. Rizk, M. H.; Lovell, D.; and Jou, W. H.: Wind Tunnel Wall Interference Corrections Based on the Euler Equations. Flow Industries, Inc., Research and Technology Division Report No. 289, 1984.

18. Gumbert, C. R.; and Newman, P. A.: Validation of a Wall Interference Assessment/Correction Procedure for Airfoil Tests in the Langley 0.3-m Transonic Cryogenic Tunnel. AIAA Paper 84-2151, 1984.

19. Gaffney, R. L., Jr.; Salas, M. D.; and Hassan, H. A.: Assessment of Wind Tunnel Corrections for Multielement Airfoils at Transonic Speeds. Third Symposium on Numerical and Physical Aspects of Aerodynamic Flows, 1985.

Unpublished:

20. Newman, P. A.: Wall Interference Theories. National Transonic Facility Research Symposium, NASA Langley Research Center, Dec. 5, 1983.

21. Adcock, J. B.: Wall Interference Experiments. National Transonic Facility Research Symposium, NASA Langley Research Center, Dec. 5, 1983.

22. Newman, P. A.; Gumbert, C. R.; and Kemp, W. B., Jr.: 0.3-m Transonic Cryogenic Tunnel User Mini-Workshop on Airfoil WIAC Procedure - Presentation Viewgraphs. NASA Langley Research Center, Feb. 6, 1985.

23. Gumbert, C. R.: User Manual for 0.3-m TCT Wall-Interference Assessment/Correction Procedure: 8- by 24-Inch Airfoil Test Section. NASA TM-87582, 1985.

IV. ADAPTED WALLS

A. Active

1. Goodyer, M. J.: The Self Streamlining Wind Tunnel. NASA TM X-72699, 1975.

2. Goodyer, M. J.: A Low Speed Self Streamlining Wind Tunnel. AGARD-CP-174, 1976, pp. 13-1 to 13-8.

3. Judd, M.; Goodyer, M. J.; and Wolf, S. W. D.: Application of the Computer for On-Site Definition and Control of Wind Tunnel Shape for Minimum Interference. AGARD-CP-210, 1976, pp. 6-1 to 6-14.

4. Judd, M.; Wolf, S. W. D.; and Goodyer, M. J.: Analytical Work in Support of the Design and Operation of Two Dimensional Self Streamlining Test Sections. NASA CR-145019, 1976.

5. Wolf, S. W. D.; and Goodyer, M. J.: Self Streamlining Wind Tunnel: Low Speed Testing and Transonic Test Section Design. NASA CR-145257, 1977.

6. Wolf, S. W. D.: Self Streamlining Wind Tunnel: Further Low Speed Testing and Final Design Studies for the Transonic Facility. NASA CR-158900, 1978.

7. Goodyer, M. J.: Developments in Airfoil Testing Techniques at University of Southampton. NASA CP-2045, 1979, pp. 415-423.

8. Ladson, C. L.: A New Airfoil Research Capability. NASA CP-2045, 1979, pp. 425-432.

9. Wolf, S. W. D.; and Goodyer, M. J.: Studies of Self Streamlining Wind Tunnel Real and Imaginary Flows. NASA CR-158831, 1979.

10. Goodyer, M. J.; and Wolf, S. W. D.: The Development of a Self-Streamlining Flexible Walled Transonic Test Section. AIAA Paper 80-0440, 1980. (AIAA J., vol. 20, no. 2, 1982, pp. 227-234).

11. Wolf, S. W. D.: Selected Data From a Transonic Flexible Walled Test Section. NASA CR-159360, 1980.

12. Wolf, S. W. D.; Goodyer, M. J.; and Cook, I. D.: Streamlining the Walls of an Empty Two-Dimensional Flexible-Walled Test Section. NASA CR-165936, 1982.

13. Wolf, S. W. D.; Cook, I. D.; and Goodyer, M. J.: The Status of Two- and Three-Dimensional Testing in the University of Southampton Transonic Self-Streamlining Wind Tunnel. AGARD-CP-335, 1982, pp. 15-1 to 15-14.

14. Wolf, S. W. D.: Control Software for Two Dimensional Airfoil Tests Using a Self-Streamlining Flexible Walled Transonic Test Section. NASA CR-165941, 1982.

15. Goodyer, M. J.: Extraction of Model Performance from Wall Data in a Two-Dimensional Transonic Flexible Walled Test Section. NASA CR-165994, 1982.

16. Wolf, S. W. D.: Aerodynamic Data From a Two-Dimensional Cambered Airfoil Section in a Shallow Transonic Flexible Walled Test Section. NASA CR-166005, 1982.

17. Wolf, S. W. D.: A Wake Traverse Technique for Use in a Two Dimensional Transonic Flexible Walled Test Section. NASA CR-165995, 1982.

18. Everhart, J. L.: A Method for Modifying Two-Dimensional Adaptive Wind-Tunnel Walls Including Analytical and Experimental Verification. NASA TP-2081, 1983.

19. Everhart, J. L.: FLEXWAL: A Computer Program for Predicting the Wall Modification for Two-Dimensional, Solid Adaptive-Wall Wind Tunnels. NASA TM-84648, 1983.

20. Webb, J.: Adaptation of Two-Dimensional Transonic Analysis Code, TSFOIL, for Use in Modeling Adaptive Wall Test Sections. NASA CR-173300, 1984, Appendix B.

21. Goodyer, M. J.: Tests on a CAST 7 Two-Dimensional Airfoil in a Self-Streamlining Test Section. NASA CR-172291, 1984.

22. Lewis, M. C.: The Status of Analytical Preparation for Two-Dimensional Testing at High Transonic Speeds in the University of Southampton Self-Streamlining Wind Tunnel. NASA CR-3785, 1984.

23. Wolf, S. W. D.: The Design and Operational Development of Self-Streamlining Two-Dimensional Flexible Walled Test Sections. NASA CR-172328, 1984.

24. Goodyer, M. J.: Computation of Imaginary-Side Pressure Distributions Over the Flexible Walls of the Test Section Insert for the 0.3-m Transonic Cryogenic Tunnel. NASA CR-172363, 1984.

25. Goodyer, M. J.; and Cook, I. D.: Two- and Three-Dimensional Model and Wall Data From a Flexible-Walled Transonic Test Section. NASA CP-2319, 1984, pp. 79-88.

Unpublished:

26. Wolf, S. W. D.: Turbine Blade Cascade Testing in a Flexible Walled Wind Tunnel. B.Sc. Honours Project, University of Southampton, April 1975.

27. Wolf, S. W. D.: Application of Data Acquisition Systems for On-Line Definition and Control of Wind Tunnel Shape. Von Karman Inst. for Fluid Dynamics, 1979.

28. Mason, B. I. F.: Development of a Program for the Flexible Wall Tunnel at Transonic Speeds. B.Sc. Honours Project, Univ. of Southampton, May 1980.

29. Rahman, A.: Comparison of Theoretical and Experimental Data of a CAST 7 Aerofoil Section. M.Sc. Thesis, Univ. of Southampton, 1983.

30. Mineck, R. E.: Status of the Adaptive Wall Test Section for the NASA Langley 0.3-m Transonic Cryogenic Tunnel. Euromech Colloquium 187, Oct. 1984.

B. Passive

1. Ferri, A.; and Roffe, G.: Experimental Investigation of Wall Shock Cancellation and Reduction of Wall Interference in Transonic Testing. NASA CR-144979, 1975.

2. Newman, P. A.; and Anderson, E. C.: Numerical Design of Streamlined Tunnels Walls for a Two-Dimensional Transonic Test. NASA TM-78641, 1978.

3. Newman, P. A.; and Anderson, E. C.: Analytical Design of a Contoured Wind-Tunnel Liner for Supercritical Testing. NASA CP-2045, 1979, pp. 499-509.

4. Anderson, E. C.: User Guide for STRMLN: A Boundary-Layer Program for Contoured Wind-Tunnel Liner Design. NASA CR-159058, 1979.

5. Campbell, R. L.: Computer Analysis of Flow Perturbations Generated by Placement of Choke Bumps in a Wind Tunnel. NASA TP-1892, 1981.

6. Newman, P. A.; Anderson, E. C.; and Peterson, J. B., Jr.: Numerical Design of the Contoured Wind-Tunnel Liner for the NASA Swept-Wing LFC Test. AIAA Paper 82-0568, 1982.

7. Newman, P. A.; Anderson, E. C.; and Peterson, J. B., Jr.: Aerodynamic Design of the Contoured Wind-Tunnel Liner for the NASA Supercritical, Laminar-Flow-Control, Swept-Wing Experiment. NASA TP-2335, 1984.